Flexible Polyurethane Foam (PUF) Recovery

An Innovative Foam Recycling Process Developed by Argonne National Laboratory

Recipient of 2000 R&D 100 Award

Visit Our Website at: http://pe.es.anl.gov

This work is sponsored by the U.S. Department of Energy, Assistant Secretary for Energy Efficiency and Renewable Energy, Office of Industrial Technologies, under contract W-31-109-Eng-38.

Recovery and Reuse of Flexible Polyurethane Foam (PUF) from Automobile Shredder Residue

Argonne National Laboratory

Introduction

Typically, obsolete cars are shredded in large hammermills for recycling of the metallic content. Shredding of cars generally results in about 25 weight per cent non-metallic reject material commonly referred to as auto shredder residue (ASR). ASR typically contains about 10 weight per cent flexible polyurethane foam. Although there is a recycle market for clean PUF, the foam content of shredder residue contains entrained automotive fluids, dirt and metal fines. Argonne National Laboratory has developed a patented process for separating the PUF from the ASR, and for cleaning the recovered foam to meet the specifications of the recycle market. (U.S. Patent No. 5,882,432; issued March 16, 1999, Attachment 1.) Clean recovered foam has a market value in North America of $0.25 to $0.30 per pound.

Stage of Technology Development

The technology was initially demonstrated in a batch-scale field test to produce 2000 pounds of cleaned PUF for evaluation by the PUF recycle market. The recovered material was found to meet the specifications of the recycle market and was also found to meet the performance criteria for new material carpet padding for re-use in automotive applications.

A continuous process with a design capacity of 100 pounds per hour was operated over a six month period in 1997 to provide data necessary for design of a full-scale system. Continuous operation of the pilot-facility in staged campaigns was achieved and maintained with no unexpected process upsets. About 7,000 pounds of PUF were successfully recovered and cleaned and supplied to the foam rebond market for testing and evaluation. The product has been found to meet the quality requirements of this market.

The heart of the system is the linear continuous wash, rinse, and dry equipment of unique design described more fully under the unit operation discussion in the Technology Description section below.

Figure 1. Wash, Rinse, and Dry Linear Equipment stage of the PUF Recycling Pilot-Plant

The photograph shows the equipment during testing at Argonne prior to the field test conducted in the latter half of 1997. As shown, the sized foam is conveyed into a hopper that meters the sized foam into the wash station. The wash station, located between the conveyor end and just on the other side of the two personnel on the steps, consists of two sections. The first section is basically a density separation for removal of heavy tramp from the sized foam. The foam floats and moves into the wash section via solution flow. In the wash section an indexed squeeze conveyor moves the foam forward to the rinse station while compressing and releasing the foam at about 20 cycles per minute. This ensures that any entrained oils and dirt are removed. The rinse station is the same design as the wash section of the wash tank. Clean foam which appears pale can be seen exiting the rinse tank as it is being fed into the linear dryer at the very top right of the photograph. The dryer is also a conveyor system with a series of rollers above the conveyor which compress and release the foam. This type of action is essential to accomplish drying of the PUF in any reasonable residence time. In a conventional rotary dryer, a residence time of about 4 hours is required. In the linear squeeze dryer designed by Argonne, the residence time is about 10 minutes.

Polyurethane Foam Separation Technology Description

The overall process consists of six basic unit operations: 1) ASR Screening and PUF Recovery, 2) Sizing, 3) Washing, 4) Rinsing, 5) Drying and 6) Baling as shown in Figure 2.

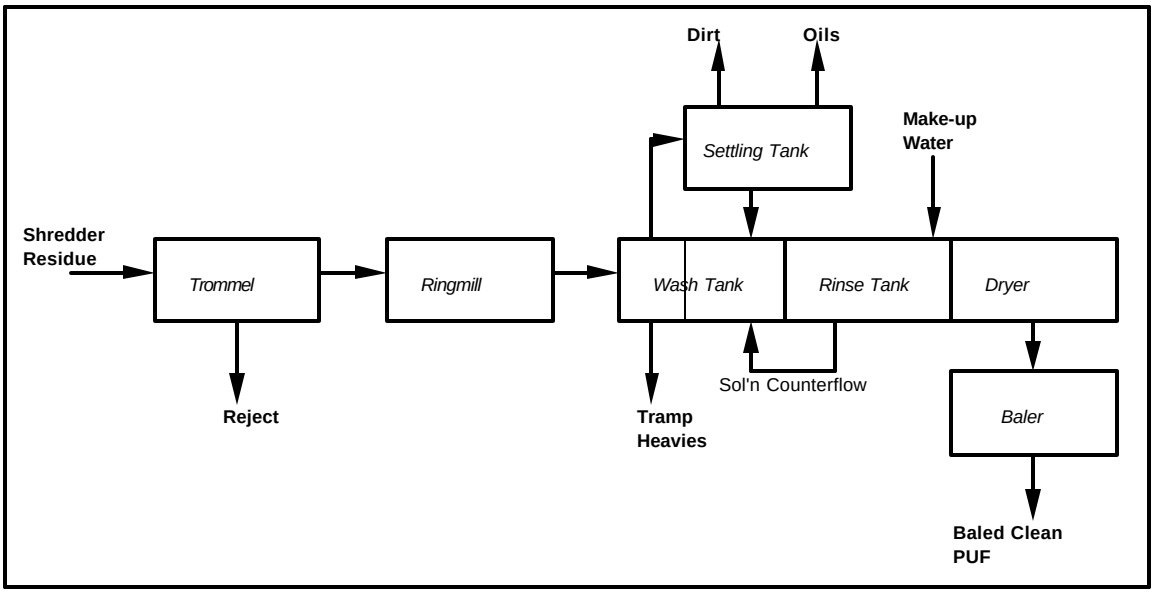

Figure 2. Block Flow Diagram of the PUF Recovery Process

Unit Operation 1: ASR Screening and PUF Recovery

The PUF can be recovered from ASR in any number of mechanisms including hand-picking. However, the more cost-effective mechanism is to recover the PUF from the non-ferrous material stream that is typically conveyed to an eddy current separator for recovery of non-ferrous metals. In this arrangement, the non-ferrous fraction from the shredder will contain all material except the ferrous metals recovered magnetically. Typically this material is fed to a trommel to reject -5/8 inch fines prior to the eddy current separator. Following the eddy current separator, the non-metallic fraction would be fed to a two-stage trommel to recover the dirty PUF. The recovered foam at this stage will vary considerably in physical dimensions.

Unit Operation 2: PUF Sizing

The PUF is then belt conveyed to a ring mill to reduce all of the foam to a consistent size; pieces of about 2 to 5 inches. Size reduction is necessary to provide effective cleaning and subsequent drying of the foam and also assists in liberating entrained dirt and metals. The sized foam is then conveyed to the washing operation.

Unit Operations 3,4 and 5: Washing, Rinsing, and Drying

Washing, rinsing, and drying of the sized foam is accomplished in a continuous, three stage linear component as previously shown in Figure 1.

Washing

The sized foam is then washed in a linear washing machine that automatically conveys the foam through the machine while subjecting the foam to a series of squeezes to reject entrained dirt. The wash tank is actually comprised of two sections. In the first section, any tramp metals or other heavies are allowed to settle as the foam is moved to the washing section. Tramp materials are screw conveyed from the bottom of the tank. The washing solution is aqueous based with a surfactant for liberation of entrained oils and dirt. Wash water is maintained between 130 oF and 180oF, depending upon the surfactant being used. The dirty wash water cycles through hydrocylones and to a settling tank where water is continuously recycled back to the wash tank. Oils are skimmed and entrained solids are screw conveyed from the bottom of the settling tank for disposal. Typically, production of 500 tons of clean foam will require processing of about 600 tons of dirty foam. The dirty foam will contain about 75 tons of entrained dirt and about 25 tons of entrained oils.

Rinsing

The rinsing operation is essentially the same as the washing except that rinsing is done with only water at 180 ^{o}F.

Drying

The clean foam is then dried in a linear squeeze conveyor dryer. Residence time in the dryer is about 10 minutes to achieve a retained moisture content of less than 2 weight per cent in the foam. Drying is accomplished with hot air.

Unit Operation 6: Baling

The cleaned, dry foam is then conveyed to a horizontal baler to densify the foam for shipment to the customer as shown in figure 3. A horizontal continuous baler is used to produce bales that weigh about 300 pounds with dimensions of 2 feet by 2 feet by 5 feet.

Figure 3. PUF Bales

Process Economics

Process economics are estimated on a design basis of 1000 tons per year of clean foam produced in an eight hour shift operating 300 days per year. This is equivalent to a design capacity of about 840 pounds per hour. This equates to the amount of flexible foam that is estimated to be recoverable from about 60 shredded cars per hour.

The total capital investment is estimated at $700,000 for all unit operations equipment. The cost does not include contractor's engineering fees, license fees, or taxes and permit fees.

Annual revenues and expenses are summarized in Table 1.

Table 1. Annual Earnings Before Interest, Taxes, Depreciation and Amortization

Annual Revenues @ $0.30/lb foam	$600,000
Credit for Avoided Disposal @ $20.00/ton	20,000
Total Annual Revenues	**$620,000**
Operating Costs	
Labor, 2 operators at $18/hour	86,400
Electricity, 150 kWh/hr @$0.10/kWh	36,000
Natural Gas, 1 million Btu/hr @ $4.00/million Btu	9,600
Chemicals, 0.01 lb/lb foam @ $0.85/lb	17,000
Disposal Costs for Wet Dirt @ $20.00/ton	8,000
Disposal Costs for Oils @ $100.00/barrel	63,500
Maintenance, @ 3.5% of Capital	22,750
Total Annual Operating Costs	**$243,250**
Annual Earnings Before Interest, Taxes, Depreciation and Amortization	**$376,750**

To obtain additional information, or to inquire about a license to this technology contact:

Edward J. Daniels
630-252-5279, voice
630-252-1342, fax

edaniels@anl.gov

Visit Our Website at: http://pe.es.anl.gov